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THE VERSATILE PAINT-MAKING PROPERTIES OF ZINC OXIDE

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THE VERSATILE PAINT-MAKING PROPERTIES OF

ZINC OXIDE

New Jersey
zinc

TECHNICAL BULLETIN
by
HARLEY A. NELSON

First Edition
March 1940—7.5M

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The New Jersey Zinc Company

THE NEW JERSEY ZINC COMPANY
(Established 1848)

160 Front Street, New York

Products Distributed By

The New Jersey Zinc Sales Company
(Incorporated)

New York Chicago Boston Cleveland San Francisco

THE CENTRAL RESEARCH LABORATORY OF THE NEW JERSEY ZINC COMPANY

PREFACE

More than 25 years ago The New Jersey Zinc Company, as manufacturers of Zinc Pigments for the Paint Industry, recognized that the complicated optical, physical and chemical relations between pigments and vehicles deserve more than casual study. Its research activities have expanded to keep pace with the demands for increased knowledge about the services that zinc pigments can perform in paint, and how they can be used to best advantage. What follows represents an attempt at a brief summary of this knowledge as it pertains to one of the most versatile of the white paint pigments—zinc oxide.

Every effort is made to insure the accuracy of the data and other material appearing in this booklet. We do not, however, guarantee the results to be obtained from the use of this information.

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THE VERSATILE PAINT-MAKING PROPERTIES OF ZINC OXIDE

The first knowledge about zinc oxide is shrouded in the antiquity of man's discovery of brass, and Pliny refers to its appearance in an impure form in the foundry furnaces of his time. These accumulations of woolly masses, still evident around zinc plants wherever zinc oxide has an opportunity to form under the proper conditions, became the philosopher's wool (lana philosophica) of the alchemists.

The modern history of zinc oxide began 200 years ago when Cramer, in Germany, described its production by burning metallic zinc. Courtois, in France, seems to have been the first to propose its use as a pigment and noted that it is not darkened by sulfur gases. Later, approximately 160 years ago, he started its manufacture and sale.

Interest also developed in America, for it is recorded that about 110 years ago the house of Dr. Fowler, somewhere in the vicinity of Franklin, New Jersey, was painted with zinc oxide made from the zinc ore deposits for which that region is famous. At the same time Leclaire, in France, whose interest was aroused because of the non-toxic and non-discoloring qualities of zinc oxide, was hard at work developing a process by the steps ore-metal-zinc oxide, later called the "indirect" or French process. Twenty years later, in America, Burrows and Wetherill developed the open grate furnace process for going direct from ore to zinc oxide, which became known as the American process and marked the real beginning of the industry in the United States.

Now, after zinc oxide has been manufactured in this country for many years, it is well recognized that there is no health hazard involved either in the handling of zinc oxide in paint plants, or as a component of paint. The Public Health Report, "Zinc In Relation to General and Industrial Hygiene," points out that exhaustive clinical and laboratory study of 24 workmen exposed over periods of time varying from 2 to 35½ years to the inhalation of varying concentrations of zinc in the form of zinc oxide, zinc sulfide, or fine metallic zinc dust, found no acute or chronic illness in any way ascribable to zinc.

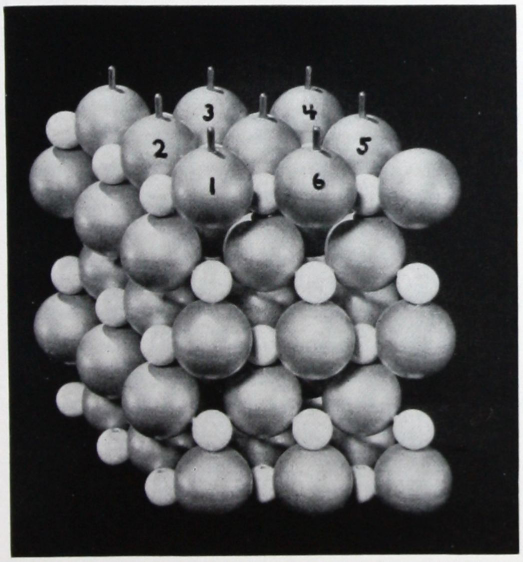
Knowledge as to why the desirable results are obtained with zinc oxide in paint has gradually accumulated from experience, and organized research has greatly accelerated the development of such information during the last three decades. Organized research on the product itself has also proved that zinc oxide is amenable to many previously unsuspected adjustments of its characteristics, and this versatility is constantly adding to its value for the paint formulator.

This accumulation of knowledge has naturally brought about some changes in ideas on the use of zinc oxide. Most important is the present trend toward thinking of zinc oxide as a substance with special optical, physical and chemical properties of such practical value that its purely pigment characteristics may be considered of secondary importance. In other words, the use of zinc oxide in paint can often be justified without the necessity for considering that it rates well up in the scale as a white hiding pigment, and that it is among the best from the standpoint of color.

PROPERTIES OF ZINC OXIDE

Zinc oxide is the simple oxidation product of zinc fume obtained either by (1) direct vaporization of zinc metal or by (2) mixing a reducing agent (coal) with a zinc ore and burning the mixture to release the zinc fume. It may also be obtained by chemical precipitation methods, producing either zinc carbonate or zinc hydroxide, which are readily converted to zinc oxide by heating, but such processes are of negligible importance in the United States.

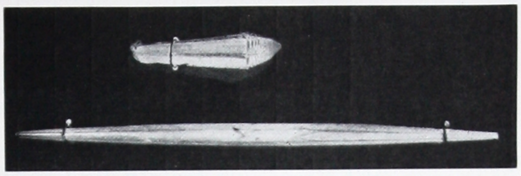
According to X-ray evidence,[1] all zinc oxides are crystalline materials built up in the form of what is known as a hexagonal close-packed lattice. This structure can be readily visualized by the model in Figure 1, which shows how the zinc and oxygen atoms dispose themselves in alternate layers. This characteristic crystal growth is also graphically illustrated by the crystals shown in Figure 2, formed under ideal crystallizing conditions by very slow and undisturbed oxidation of zinc metal fume within a pile of zinc oxide furnace residue.



Large spheres represent zinc atoms. Small spheres represent oxygen atoms. The positions of the zinc atoms numbered from 1 to 6 illustrate the arrangement in the basal plane of a hexagonal close-packed lattice.

Model of a Zinc Oxide crystal.

FIGURE 1



Zinc Oxide crystals (rock oxide) collected from furnace residue, showing characteristic crystal growth. (Enlarged about 33⅓%.)

FIGURE 2

Optical Properties

Zinc oxide has some optical, physical and chemical properties that are common to all crystalline materials that qualify as hiding pigments, and has other properties that are definitely unique. Refractive index is in the first group and, in a general way, places zinc oxide in the intermediate hiding power class when compared with silicious inerts and zinc sulfide:

	Refractive Index
Average paint vehicle	1.4 —1.5
Silicious inerts	1.45—1.55
Barium sulfate	1.64
Zinc oxide	2.0
Zinc sulfide	2.37

Practical hiding power is recognized as also depending on the nature of the pigment-binder interface (or the physical structure of the paint film) and on the brightness and particle size of the pigment, so it cannot be stated except in terms of finished paints. The more unusual zinc oxides, such as the colloidal type, represented by Kadox, and the extremely coarse type, represented by XX-104, have lower values because they are both outside the particle size range for optimum hiding power for zinc oxide, which is from 0.2 to 0.3 micron.[2] Kadox and XX-104 are often

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[1] M. L. Fuller—The Axial Ratio and Lattice Constants of Zinc Oxide—Science, Vol. 70, 1929, p. 196.

[2] G. F. A. Stutz—The Scattering of Light by Dielectrics of Small Particle Size—Journal of the Franklin Institute, Vol. 210, No. 1, July 1930, p. 67.

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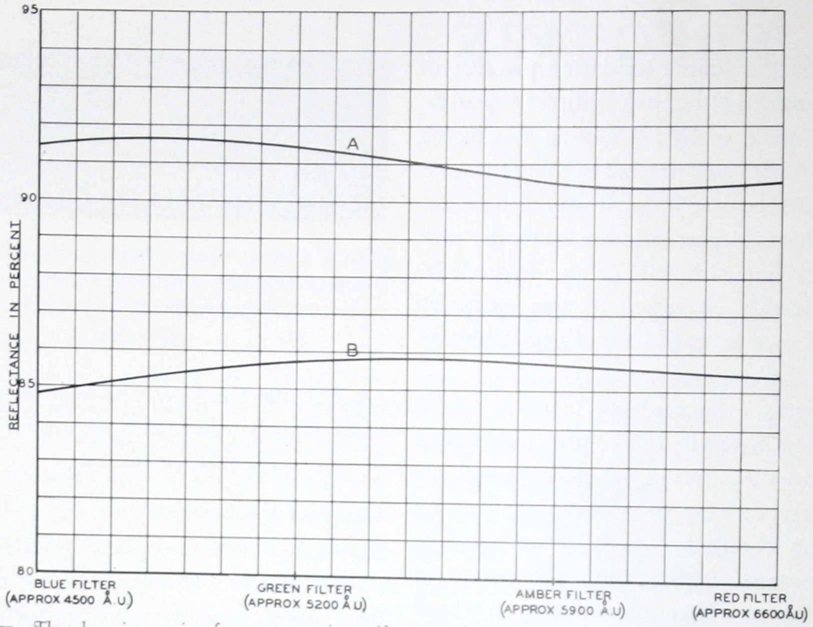

NOTE—*The values given are in reference to magnesium oxide as a standard taken as having 100% reflectance. The absolute reflectance values will be somewhat lower, since magnesium oxide does not reflect 100% of the light. Reflectance values for magnesium oxide ranging from 98% to 99.4% are to be found in the literature.*

A—*Type for use in enamels.* B—*Type for use in exterior paints, etc.*

Typical reflectance (brightness) values for Zinc Oxides determined in pastes with pale oil. Zinc Oxides have a relatively high and uniform degree of transparency to light throughout the visible spectrum, which is necessary for producing a white pigment of good brightness and color.

FIGURE 3

used where the chemical effects of zinc oxide are wanted in different degrees without normal pigmenting qualities.

Zinc oxide crystals have a relatively high and uniform degree of transparency to light throughout the visible spectrum, which is necessary for producing a white pigment of good brightness and color. Zinc oxides can be made in a wide range of brightnesses and color tones, depending on the requirements for the particular use, but the brightness-color curves in Figure 3 are typical of the most used grades.

On the other hand, the transmission qualities of zinc oxide in the ultra-violet region of the spectrum are unique because of the sharpness with which the radiations are cut off at about 3600 Å U,[3,4] therefore preventing the transmission of ultra-violet (actinic) light that has the most destructive effect on organic binders. Ultra-violet transmission curves for typical pigments are shown in Figure 4. Figure 5 also demonstrates this difference between pigments as it is revealed when ultra-violet light is used for illumination in making photomicrographs.

The significance of this property became ap-

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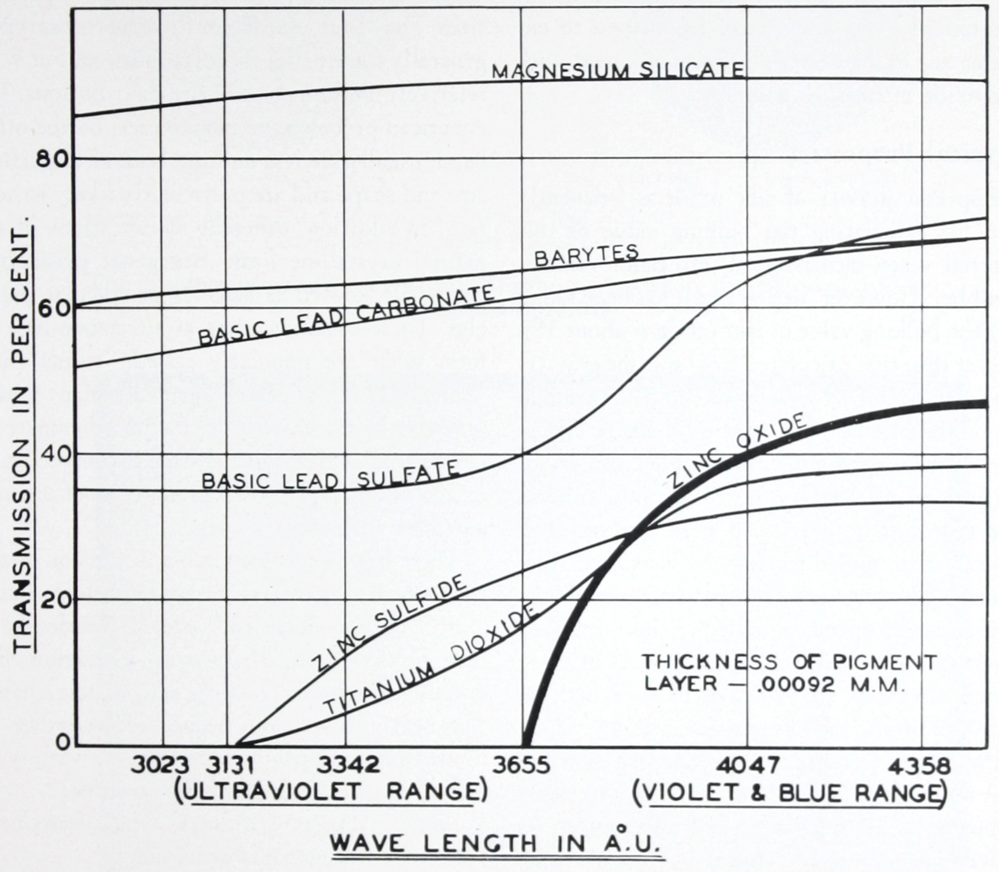
[3] A. H. Pfund—Some Optical Properties of White Paint Pigments in the Ultra-Violet Spectrum—Proc. A.S.T.M., Vol. 23, Part 2, 1923, pp. 369-378.

[4] G. F. A. Stutz—The Testing of Paint Pigments for Transparency to Ultra-Violet Radiation—Journal of the Franklin Institute, Vol. 202, July 1926, pp. 89-98.



Transparency of white pigments to ultra-violet light radiation. Zinc Oxide is opaque to the destructive ultra-violet (actinic) rays. This is a useful property because it retards the aging effects of light on the binder.

FIGURE 4

parent in the early studies [5,6,7] of the effects of ultra-violet light on paint films. A very rapid disintegration of unpigmented oil films was shown, as compared with the partial protection offered to the binder by the semi-transparent pigments, and the effective protection obtained with zinc oxides. This knowledge has helped to explain many of the desirable effects obtained with zinc oxide in exterior paints.

Physical Properties

The specific gravity of zinc oxide is frequently used for calculating the bulking value of this material when incorporated into paint vehicles or rubber. However, in practice it has been found that the bulking value of zinc oxide is about 1% greater than that calculated from specific gravity. This may be due to some adsorbed gases remaining on the surface of the zinc oxide or to formation of zinc soaps around the particles after grinding into paint vehicles or milling into rubber. The true specific gravity of pure zinc oxide is 5.65, as determined recently by X-ray measurements and by pycnometer displacement methods. The apparent specific gravity of zinc oxide in practical use, however, averages about 5.6, which calculates to 46.73 pounds per gallon, and 0.02140 gallon per pound.

Proper particle size and particle size distribution for the job at hand are other requirements common to all pigments, and zinc oxide has proved amenable to adjustment over a wide range of average particle sizes, from practically colloidal pigment approximating 0.12 micron to relatively coarse pigment approximating 5 microns in diameter. Figure 6 shows typical particle size distribution curves for some zinc oxides within the particle size range that is of most common interest. The versatility of zinc oxide from this standpoint is a great advantage because particle size modification can be employed for so many practical purposes, such as adjustments in amount of reaction between the pigment and the vehicle, consistency, gloss, hardness of the film, and weathering characteristics.

The particle shape of zinc oxide is also relatively amenable to control. Classification of the forms that appear under the microscope can be made in only a general way. The most common form is nodular—usually more or less irregular—which is obtainable in a wide range of particle sizes. The "Seal" oxides, or French process types, generally come under this classification, but with relatively uniform particle size distributions. The American process type zinc oxides, on the other hand, usually are less uniform both as to particle size and shape and are particularly likely to contain, in addition, different modifications of the natural crystalline form (hexagonal prismatic), commonly known as acicular or spicular particles. These sometimes join at a common base to form what are popularly called "twins" and "threelings." The percentage of acicular crystals may also be increased until they predominate to any desired degree, but the usual commercial zinc oxides of this type consist of mixtures of acicular particles with other shapes.

There has been considerable discussion of the part which shape plays in the durability of zinc oxide. Both nodular and acicular oxides have been observed, and there is no indication that durability depends entirely on particle shape. The best average performance seems rather to result from a proper distribution of a variety of shapes and sizes of zinc oxide particles.

Figure 7 illustrates different types of products that are now commonly available.

Chemical Properties

In its pure form, zinc oxide is very slightly on the alkaline side. Under normal manufacturing conditions, the surface adsorbs reactive gases from the atmosphere, so pH measurements on water slurries of commercial products result in values rang-

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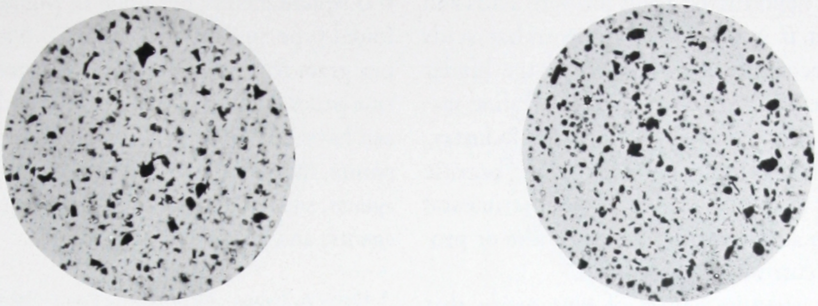
[5] Harley A. Nelson—Stress Strain Measurements on Films of Drying Oils, Paints and Varnishes—Proc. A.S.T.M., Vol. 21, 1921, pp. 1111-1134.

[6] Harley A. Nelson—Accelerated Weathering of Paints on Wood and Metal Surfaces—Proc. A.S.T.M., Vol. 22, Part 2, 1922, pp. 485-503.

[7] E. H. Bunce—Zinc Oxide in Exterior Paint—Paint, Oil & Chemical Review, Vol. 84, December 1, 1927, pp. 12-15.

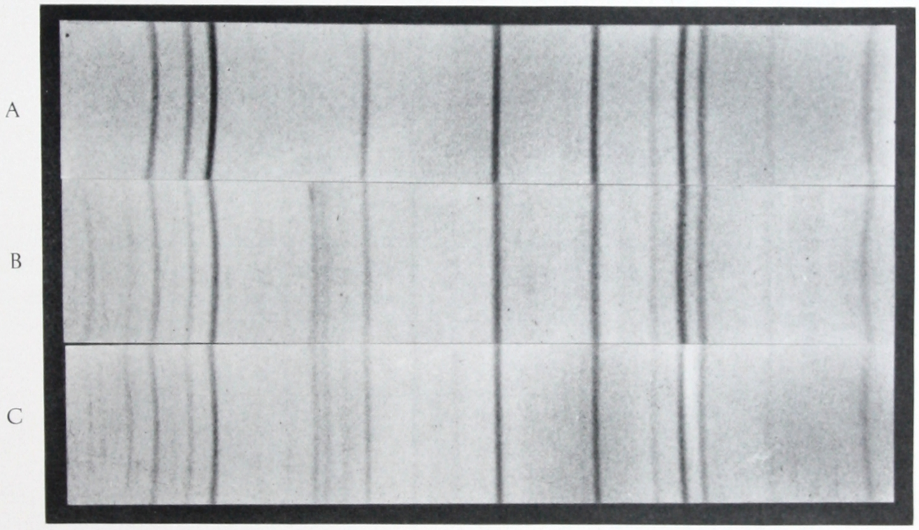


Blended 35% Leaded Zinc Oxide

Co-fumed 35% Leaded Zinc Oxide

Photomicrographs of Leaded Zinc Oxide by ultra-violet light of 2750 Å U. Dark particles are opaque Zinc Oxide crystals. Clear particles are transparent Normal Lead Sulfate and Basic Lead Sulfate crystals.

The photomicrographs reveal no differences between the blended and co-fumed products.



A—Lead-free Zinc Oxide
B—Co-fumed 35% Leaded Zinc Oxide
C—Blended 35% Leaded Zinc Oxide

The vertical lines outline the X-ray patterns of the three Oxides. It is to be noted that all the lines in the Lead-free Zinc Oxide pattern carry through both Leaded Zinc Oxide patterns. The lines appearing in the Leaded Zinc Oxides, and not in the Lead-free, are due to Lead Sulfates. These lines are the same in both the blended and co-fumed Leaded Oxides, showing that there is no difference between the two products.

X-ray diffraction patterns showing that Leaded Zinc Oxides produced by mixing Zinc Oxide and Lead Sulfates are no different in composition from those obtained by producing the fumes in the same furnace (co-fuming).

FIGURE 5

ing from 7.0 to 8.0. Since zinc oxide is amphoteric, it is a neutralizing agent for both acids and alkalies, but it is the ability to neutralize acids and acid decomposition products in the binder without the addition of a strongly alkaline material that is of interest to the paint industry. This is a particularly useful function, because these acid materials usually have detrimental effects, such as discoloring the paint film or promoting the corrosion of metals.[8,9]

It is the reactive nature of zinc oxide that accounts for many of its unique qualities in paint. Ordinarily, the degree to which this reactivity functions depends on particle size, or more accurately on surface area, which can range from 6.0 square meters per gram of pigment in a colloidal type zinc oxide down to 0.6 square meter per gram for the larger particle sizes. The reaction products between zinc oxide and the vehicle can have diverse and far-reaching influences on paints, functioning as dispersing agents, bodying agents, suspending agents, densifying and sealing agents, and hardening agents.

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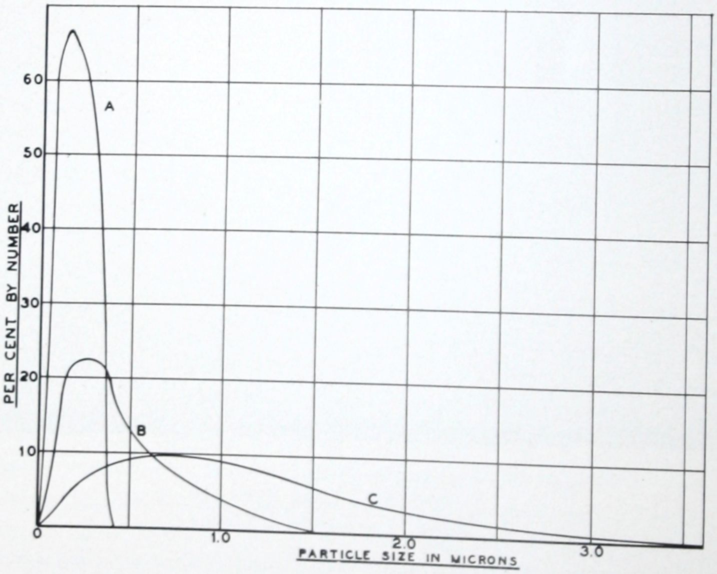
[8] Harley A. Nelson—Metal Priming Paints—Inhibiting Qualities and Influence of Reactions within the Paint Film—Industrial & Engineering Chemistry, Vol. 27, January 1935, p. 35.

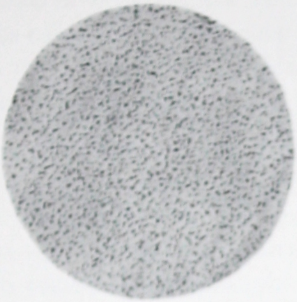
[9] H. J. Wing—Reaction between Paint Films and Zinc Surfaces—Industrial & Engineering Chemistry, Vol. 28, February 1936, p. 242.



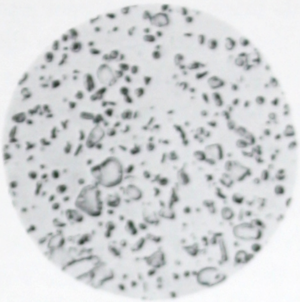
A—Kadox—fine particle size Zinc Oxide.
B—XX-50—American process type Zinc Oxide, intermediate particle size.
C—XX-503—American process type Zinc Oxide, large particle size.

Particle size-frequency curves for typical Zinc Oxides.

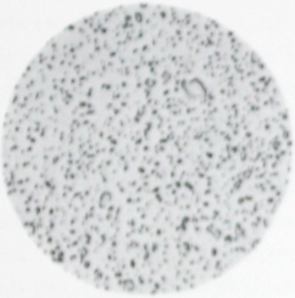
FIGURE 6



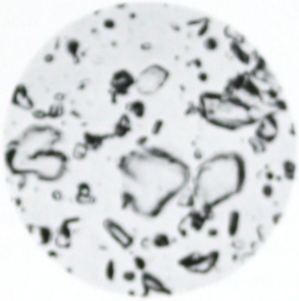
Nodular type Zinc Oxide of uniform and fine (practically colloidal) size. Average particle size approximately 0.12 micron.



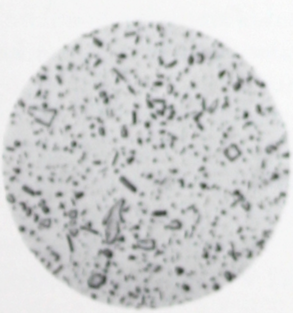
Nodular type Zinc Oxide of larger size and relatively uniform size distribution. (Relatively free of colloidal fines.) Average particle size approximately 1.3 microns.



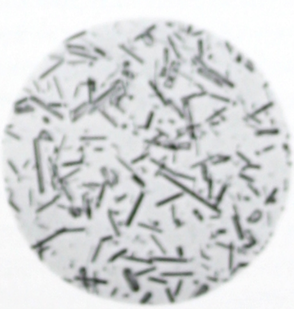
Nodular type Zinc Oxide of intermediate size (considerable colloidal fines) and less uniform size distribution. Average particle size approximately 0.3 micron.



Nodular type Zinc Oxide of large size and relatively uniform size distribution. (No colloidal fines.) Average particle size approximately 5 microns.



Multiform type Zinc Oxide of intermediate size (relatively low in colloidal fines) and quite non-uniform size distribution. Average particle size approximately 0.4 micron.



Acicular type Zinc Oxide, relatively non-uniform in size distribution. Because of the high proportion of acicular particles, it is impractical to estimate the average particle size.

Photomicrographs of some typical Zinc Oxides (magnification 1285 X).

FIGURE 7

Zinc Oxide of Low Reactivity

Obviously, its reactivity sometimes puts limitations on the use of zinc oxide, as in the case of some synthetic resin vehicles. Realizing the valuable properties inherent in zinc oxide, attention has been given to the development of less reactive vehicles to permit the use of zinc oxide without major consistency changes. However, the latest contribution to this problem comes from the pigment side in the form of zinc oxide with a less reactive surface, at present represented by XX-505. Because of the complexity of the vehicle situation, it is impossible to make sweeping generalizations or classify the results according to types of vehicles, but experience has demonstrated that paints of practical stability can be made with XX-505 in many cases where standard zinc oxides are out of the question. The interesting thing about this type of zinc oxide is that, according to evidence at hand, it not only produces most of the desired effects obtained with other zinc oxides, but in some cases it shows definite improvement over these.

Fungicidal Properties

The mild but effective fungicidal action of zinc oxide gives it a unique position among white pigments. However, the fact that zinc oxide acts fungicidally toward vegetable growth must not permit this to be confused with the property of toxicity. Zinc oxide is in no sense toxic; it is used in a great many medicinal and cosmetic preparations.

The effectiveness of zinc oxide for controlling mildew growth cannot be ascribed to reactivity in the sense that it results in soap formation and surface hardening effects on the paint film. Investigators[10] now generally accept the view that the small amounts of water soluble zinc salts formed by reactions with impurities in the atmosphere and acid decomposition products from the binder are sufficient to account for the results. Most fungi will not grow in contact with zinc oxide, which fact is now taken advantage of in other fields, as by adding it to the surface soil to control fungus attacks on young plants ("damping off").

Other Properties (Catalytic Nature)

Explanations based on the better known properties of zinc oxide have seemed inadequate for some of the effects obtained with it, the most notable example being the better gloss retention and general weather resistance of the surface film of binder associated with exterior paints containing zinc oxide. The evidence apparently rules out zinc soap as being the effective agent. Likewise, since a film of oil lies over the top pigment layer, the recognized opacity of zinc oxide to ultra-violet light cannot offer an explanation. However, during the past ten years, the literature[11] on catalysis in synthesis of alcohols, etc., has referred to the use of zinc oxide as a catalyst. From this it has been suspected that zinc oxide might act as a polymerization catalyst in paint vehicles. Preliminary tests have given reasonable evidence that such reactions are promoted in zinc oxide paint films and can be distinguished from the effects of zinc soaps.

The idea that zinc oxide can serve as a polymerization catalyst is highly important in view of the general desirability of polymerization changes in oils and resins, as contrasted with the undesirable effects of oxidation changes. Examples that are well known are the better resistance to water and to weather of polymerized oils and resins and of baked (heat polymerized) films.

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[10] S. Werthan—Zinc Pigments in Relation to Southern Climatic Conditions—Official Digest, Federation of Paint & Varnish Production Clubs, No. 147, September 1935, p. 321.

[11] D. S. Cryder and Per K. Frolich—Catalysts for the Formation of Alcohols from Carbon Monoxide and Hydrogen—Industrial & Engineering Chemistry, Vol. 21, September 1929, pp. 867-871.

REASONS FOR USING ZINC OXIDE IN PAINT

The previously mentioned optical, physical and chemical properties can be grouped into the following definite qualities that are factors in obtaining the results produced by zinc oxide:

a—Reactivity
  Acid adsorption and neutralizing power
  Soap formation

b—Catalytic effects
  Polymerization

c—Fungicidal properties

d—Opacity to ultra-violet light

e—Particle size and shape

f—Color and hiding power

It is obvious that a pigment in which such a variety of properties is combined should serve many purposes in paint. Sometimes the results that are of interest can be readily traced to one of the major properties, but in many cases the source of the effect is not readily identified since two, or even more, properties may be involved. In what follows, an effort will be made to trace these connections for the sake of developing a better understanding of what is back of the practical purposes for which zinc oxide is being used.

Ease of Mixing and Grinding

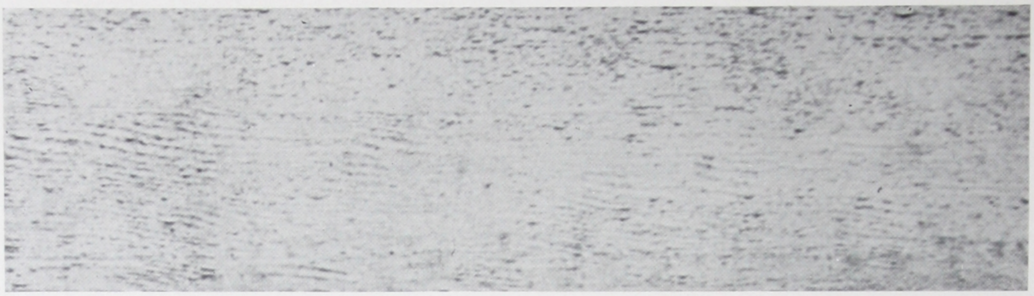
The usefulness of zinc oxide is evident even in the first step in the paint manufacturing process. Aside from the fact that zinc oxide is free from aggregates, its easy mixing and grinding qualities are definitely due to surface activity, which promotes wetting of the surface of each individual particle by the vehicle. In addition, as with many compounds of zinc, the soaps formed promote the wetting and dispersion of other pigments that are normally more difficult to mix and grind. Notable examples are the hard grinding colors, such as iron blues, and zinc oxide is considered a general standby in the plant whenever such grinding problems are encountered.

Consistency Control (Leveling, Non-sagging, Suspension)

The important characteristics that are associated with consistency are controlled to a large degree by two well recognized opposing forces which exist in paint. These are (1) the force that tends to bring about flocculation of the pigment and (2) the force that tends to keep the pigment in a dispersed state. Flocculation results in increased false body and improved suspension, whereas dispersion results in better flow and leveling. Because of its reactive surface and the soaps that can be formed with it (depending on the vehicle), zinc oxide can act strongly to produce either flocculation or dispersion. It is frequently desirable to use zinc oxide in paint for this property in order to balance the effects of other ingredients. The desired adjustments to obtain improved body, leveling, non-sagging and suspension can be made by proper selection of the zinc oxide since it is available in a wide range of particle sizes, shapes, and degrees of reactivity. A classic example of these beneficial properties of zinc oxide is the perfect leveling, good non-sagging and good pigment suspension that is characteristic of well-dispersed, high zinc oxide enamels.

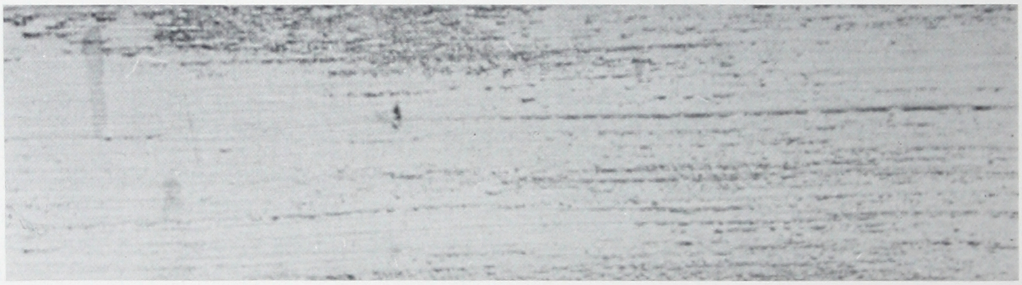
Penetration Control and Sealing

Since, due to its reactivity, zinc oxide is well wetted by the vehicle, it tends to hold the non-volatile binder within the paint film, which will result in denser and more homogeneous films and better sealing. This is substantiated by zinc oxide-containing interior undercoats and exterior wood primers. Soap formation undoubtedly is an important factor in this, but any changes that solidify the structure of the binder are steps in the right direction, so polymerization changes may also be contributing factors.



Zinc Oxide-free primer . . . Lead—Zinc type finish coat.

Zinc Oxide in primer . . . Lead—Zinc type finish coat.



Zinc Oxide-free primer . . . Titanium-Barium—Lead—Zinc type finish coat.

Zinc Oxide in primer . . . Titanium-Barium—Lead—Zinc type finish coat.

(Exposed 3 years—vertical.)

Elimination of compatibility failures between special primers and finish coats by including Zinc Oxide in the special primer.

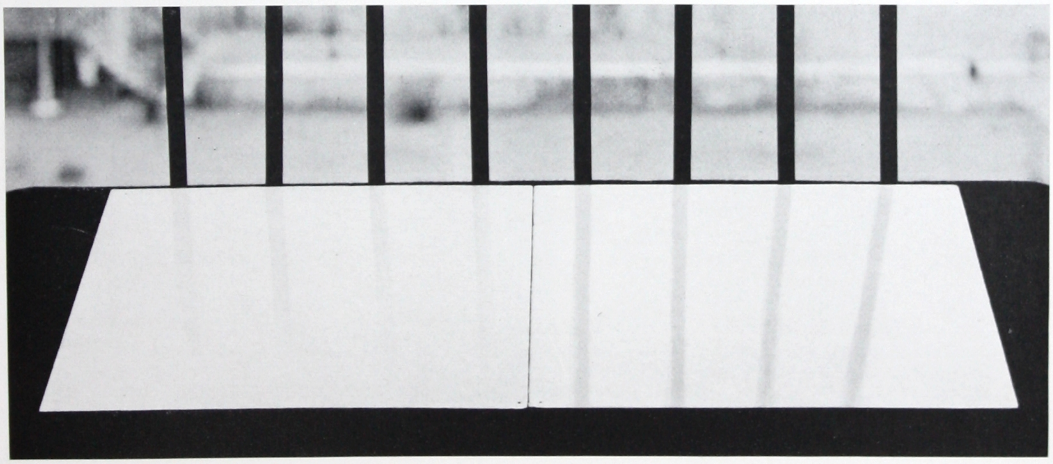
FIGURE 8

Drying

It has long been known that the presence of zinc oxide results in the formation of firmer films that are more uniformly dried throughout, and this property can be used to advantage whenever, for any reason, oils with limited hard drying properties must be used in larger amounts. The evidence of this property of zinc oxide is very marked, although zinc cannot be classified as a drying metal in the sense of being an oxygen carrier. Recently, many interesting observations have been made on the beneficial effects on drying of oil soluble zinc soaps. One conclusion arrived at is that these soaps have a peptizing action that prevents precipitation of the drier and thus promotes better distribution of the drier throughout the film. Another conclusion is that, because the initial surface set is retarded, the film is kept "open" with the result that there is opportunity for uniform through drying that reduces surface wrinkling troubles. From these views, it would be assumed that this is a case where the reactive property is a determining factor, and the general experience is that the most marked effects are obtained with the more reactive types of zinc oxide. However, since the improvements obtained are so much in line with what would be expected from increased polymerization of the binder, it is reasonable to suspect that this is a case where catalysis of polymerization might also be a factor in the results.

Hardening or Film Solidifying Qualities

The solidifying effect of zinc oxide on the film may bring about a number of obviously desirable results in service, such as resistance to abrasion, marring and washing of interior and exterior paints in general. An important case in which this effect is used to advantage is where so-called compatibility difficulties between successive coats of house paints are involved. The proper balance of physical properties in successive coats of a freshly applied paint system is of practical importance, as illustrated by the results of exposure tests shown in Figure 8, and neither added zinc soaps nor driers nor other hardening agents appear to be as effective as zinc oxide for restor-



Without Zinc Oxide *With Zinc Oxide*

The better gloss retention is represented by the greater definition of the reflection of the black bars.

Contrasts in gloss retention of interior gloss whites after three years on a wall under normal room conditions.

FIGURE 9

ing this balance. This generalization is one that applies with moderately reactive zinc oxides, such as XX-503, as well as with the more reactive products, and it is probable that catalytic effects on the binder are involved.

Gloss and Gloss Retention

The easy dispersion quality of zinc oxide, which is associated with its active surface, and its good texture naturally favor better initial gloss. However, other conditions do influence the results, since even very good pigment dispersions may lose gloss during or immediately after the drying stage. Cases of the latter type generally involve some reaction with, or selective adsorption of, an ingredient of the vehicle that normally serves to keep the other ingredients in a dispersed state, as in the case of overcooked oil vehicles. The addition of zinc oxide generally results in proportionate improvements in both initial gloss and gloss retention, as illustrated by Figure 9.

As previously mentioned, the gloss retention of exterior paints containing zinc oxide has been variously ascribed to the influence of zinc soaps and to the ultra-violet opacity of zinc oxide. Considering the known superiority of polymerized oil and resin films in resistance to moisture and light, it is reasonable to believe that increased polymerization of the surface film of binder would be the important factor in both the better gloss retention and the initial chalking resistance that are characteristic of zinc oxide-containing paints.

Discoloration and Yellowing Prevention

One of the characteristics that caught the attention and interest of those who first tried zinc oxide as a paint pigment was that paints containing it remained white under conditions that caused other white paints to discolor. Essentially, this is due to the reactivity of zinc oxide and the fact that most compounds of zinc are white. The principal external causes of paint discoloration are sulfur gases present in the atmos-

TABLE I

YELLOWING IS DECREASED BY ADDING ZINC OXIDE

	*Yellow Saturation Values**	
	Before Washing	*After Washing*
Mill Gloss 1A (without Zinc Oxide)**	23.5	18.1
" " 1B (with Zinc Oxide)**	15.3	11.0
" " 2A (without Zinc Oxide)**	16.9	14.4
" " 2B (with Zinc Oxide)**	14.2	9.6
" " 3A (without Zinc Oxide)**	24.8	23.4
" " 3B (with Zinc Oxide)**	12.8	9.3
" " 4A (without Zinc Oxide)**	24.5	35.4
" " 4B (with Zinc Oxide)**	13.3	9.0
Synthetic Architectural Enamel A (without Zinc Oxide)***	14.7	
Synthetic Architectural Enamel B (with Zinc Oxide)***	7.1	
Modified Lacquer Enamel A (without Zinc Oxide)** (See Figure 10)	30.8	
Modified Lacquer Enamel B (with Zinc Oxide)** (See Figure 10)	16.8	

*Lower yellow saturation values indicate less yellowing as shown in the Zinc Oxide-containing paints. Yellow saturation is determined by formula:

$$\frac{\text{Reflectance in yellow}-\text{Reflectance in blue}}{\text{Reflectance in green}}=\text{Yellow saturation.}$$

For example, a surface with equal reflectance values in both the yellow and blue ranges would have zero yellow saturation.

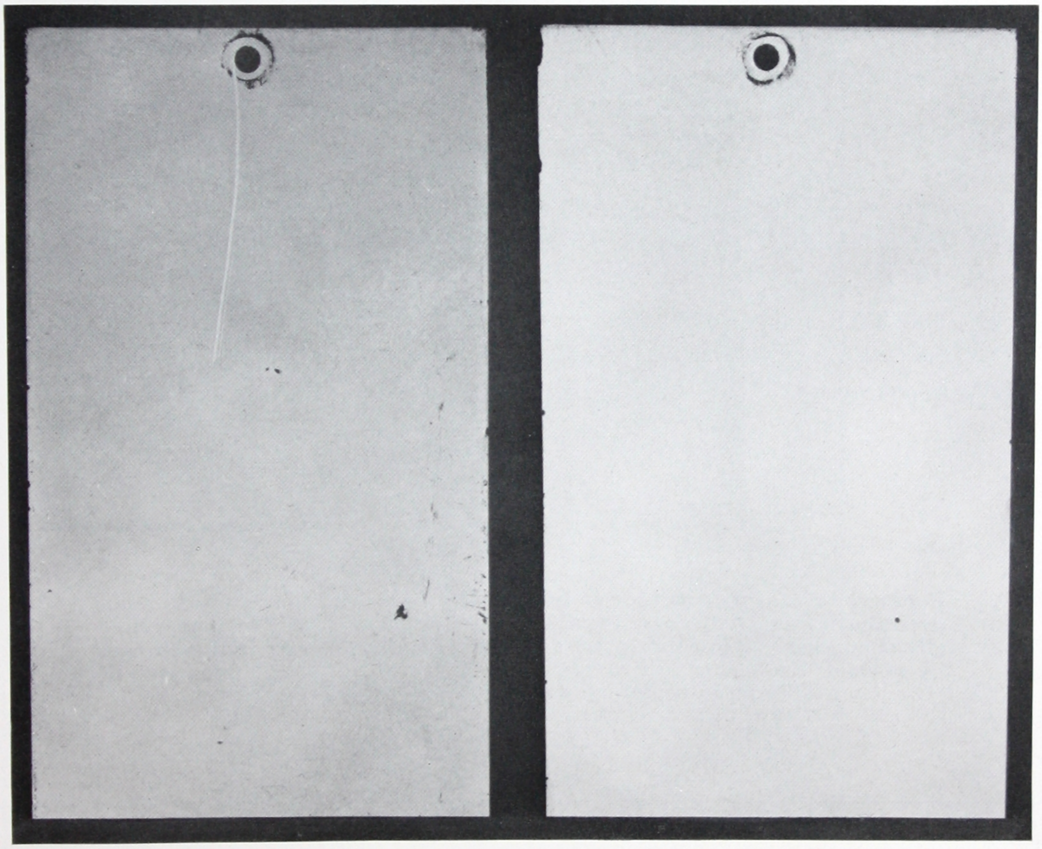
**Six years on wall.

***Ten months on wall.

phere in various forms, but particularly in the form of sulfide sulfur. The reaction product in this case, zinc sulfide, is in itself a brilliant white compound.

Other causes of discoloration (usually yellowing) have their source within the film and are formed by and during the changes that accompany the drying, aging, weathering or baking of the usual organic film-forming binders. These compounds may be yellow or brown, or they may induce such color changes in the rest of the film due to their acid nature. The presence of zinc oxide in the film can and does neutralize or retard the formation of these active compounds, and decreases yellowing, as shown by Table 1 and Figure 10. Extreme reactivity is not necessary, since all normal zinc oxides show this effect.

While the reactivity of zinc oxide undoubtedly is the important factor in this case, it is worth while to consider that polymerization changes do not promote yellowing, as do oxidation changes in the film. Consequently, the favorable results might, in part, be due to the promotion of polymerization by zinc oxide at the

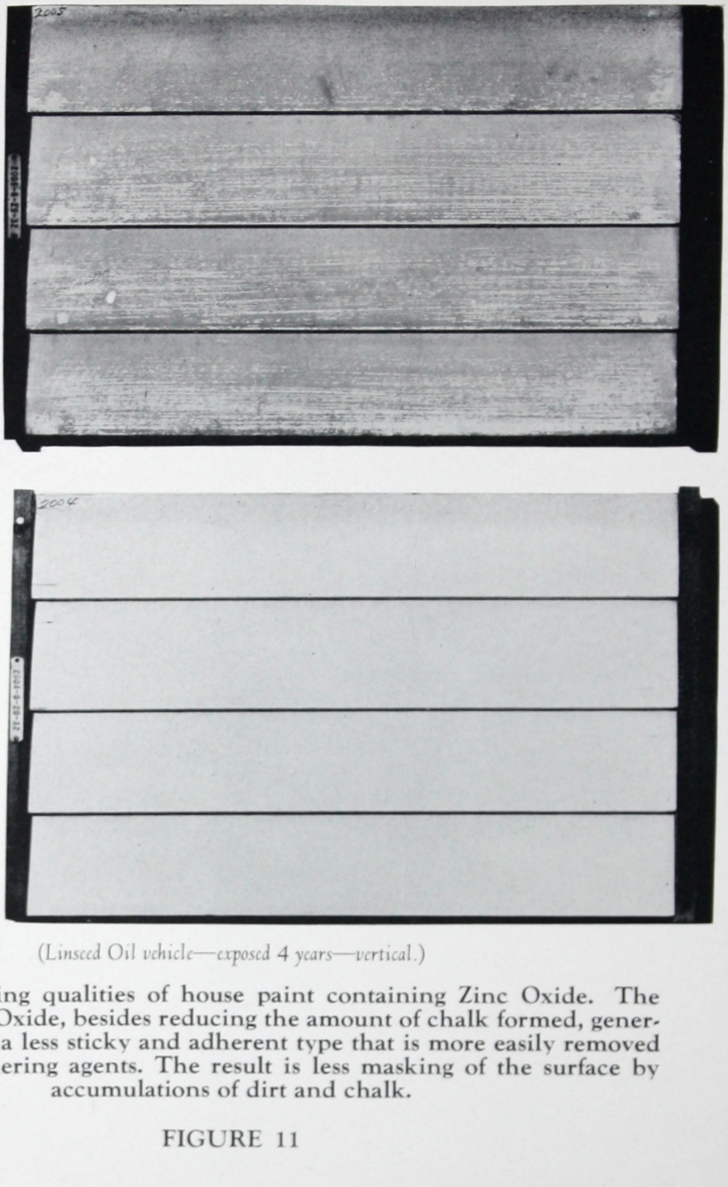


100% TiO_2
Yellow Saturation 30.8 (see Table 1)

50% TiO_2
50% ZnO
Yellow Saturation 16.8

Discoloration (yellowing) of interior lacquers containing Alkyd Modified Resin after 6 years on wall. The presence of Zinc Oxide serves to neutralize the colored and more or less acid products that are normally formed when drying oil and resin films age.

FIGURE 10



A

45% Titanium-Barium
35% Basic Carbonate White Lead
20% Silicious mixture
(Chalk is sticky and adheres, and therefore holds dirt.)

B

45% Titanium-Barium
35% Zinc Oxide
20% Silicious mixture

(Linseed Oil vehicle—exposed 4 years—vertical.)

Better self-cleansing qualities of house paint containing Zinc Oxide. The presence of Zinc Oxide, besides reducing the amount of chalk formed, generally changes it to a less sticky and adherent type that is more easily removed by normal weathering agents. The result is less masking of the surface by accumulations of dirt and chalk.

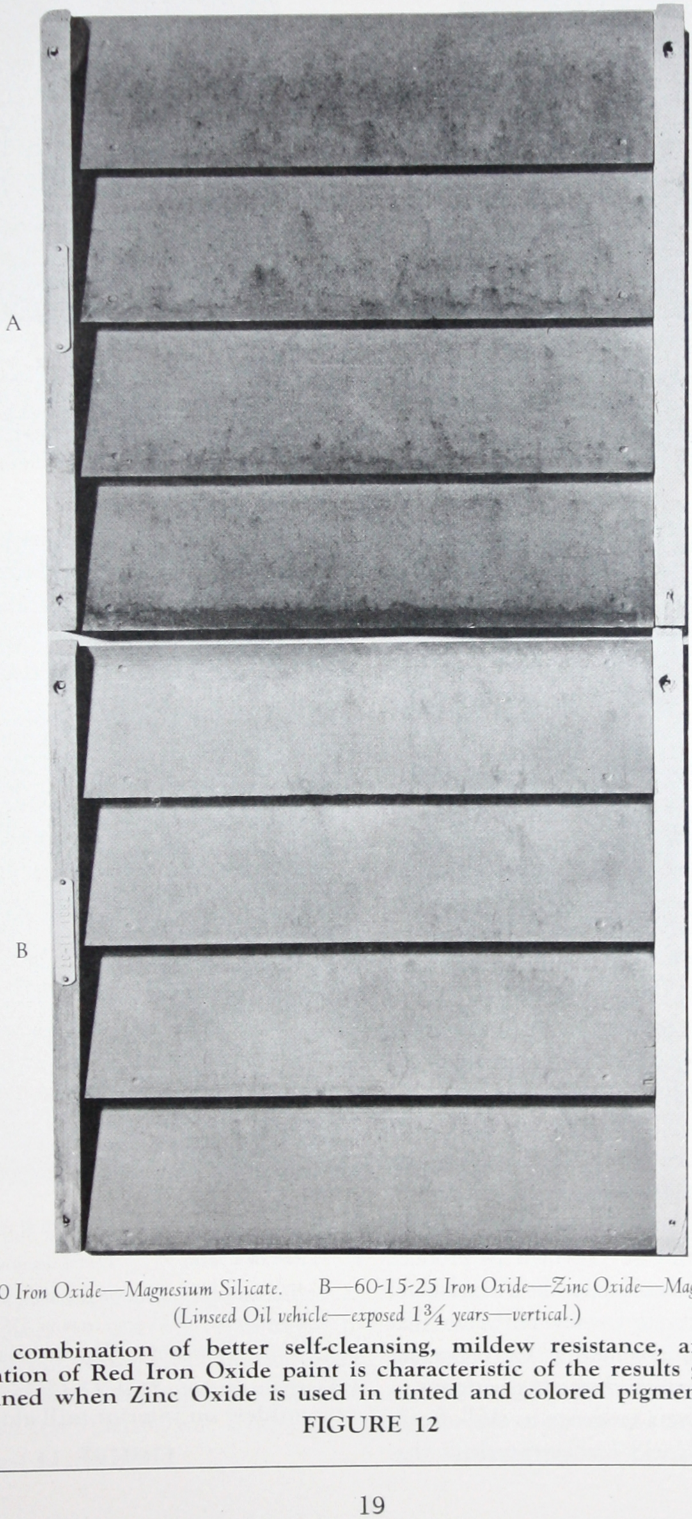
FIGURE 11

expense of oxidation. Also, any influence that promotes polymerization will develop better moisture resistance, which is a step in the right direction since moisture (humidity) is an important factor in promoting the yellowing of paint films.

Color and Tint Retention

One of the outstanding properties of zinc oxide, apparent in all types of paints where it is incorporated, is zinc oxide's quality of improving color and tint retention.

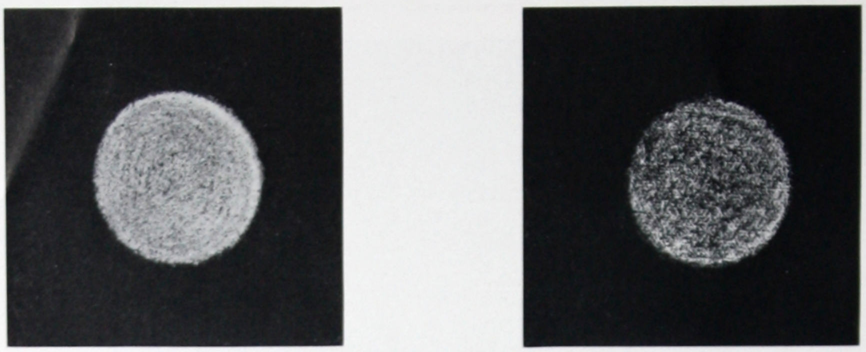
The well-known favorable position of zinc



A—70-30 *Iron Oxide—Magnesium Silicate.* B—60-15-25 *Iron Oxide—Zinc Oxide—Magnesium Silicate.*
(Linseed Oil vehicle—exposed $1\frac{3}{4}$ *years—vertical.)*

This combination of better self-cleansing, mildew resistance, and color retention of Red Iron Oxide paint is characteristic of the results generally obtained when Zinc Oxide is used in tinted and colored pigment paints.

FIGURE 12



Paint containing no Zinc Oxide (Chalk is abundant and sticky.) *Paint with Zinc Oxide.*

Chalk was removed by revolving black paper under pressure against the surfaces of the panels with a Hercules Chalk Tester. The whiter the mark, the greater the amount of chalk represented on the exposed panel.

Zinc Oxide reduces the amount, and changes the nature, of the chalk on exterior house paints.

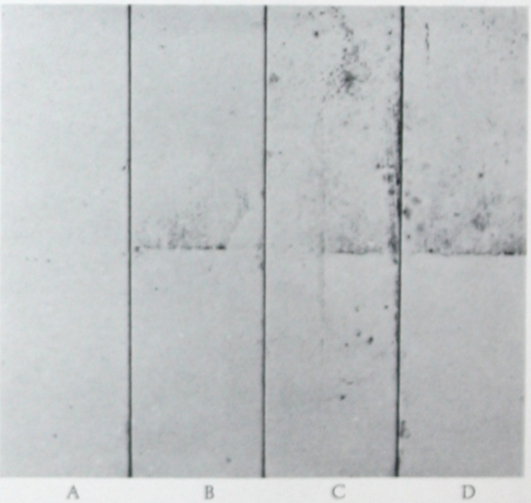
FIGURE 13

oxide in this field is generally ascribed to reduced chalking tendencies (see Figure 11), although there are a large number of cases where color changes not involving chalking are reduced or prevented with zinc oxide. Improved results in cases of the latter type might be due to neutralization by zinc oxide of decomposition products formed in the binder, these decomposition products otherwise having detrimental action on the color. In either case, opacity of zinc oxide to ultra-violet light and increased moisture resistance of the binder are important factors.

Chalking, Nature of the Chalk and Dirt Shedding (Self-Cleansing)

Zinc oxide protects the underlying layers of the binder from the action of ultra-violet light and thus retards chalking and erosion, as illustrated by Figure 13, but this does not necessarily explain why the surface skin of the binder resists exposure so much longer when zinc oxide is present. Increased resistance to moisture through polymerization would be expected to produce this result, as pointed out under the discussion of gloss retention, especially in view of the fact that absorption of moisture by the film is an important factor in promoting photochemical reactions.

Pigments that have a tendency to chalk freely generally form a "sticky" adherent chalk that promotes dirt retention and masks the surface to produce a faded appearance of tinted paints. The addition of zinc oxide changes the nature of this chalk to a "non-sticky" type. Consequently, dirt shedding (self-cleansing) is actually promoted if

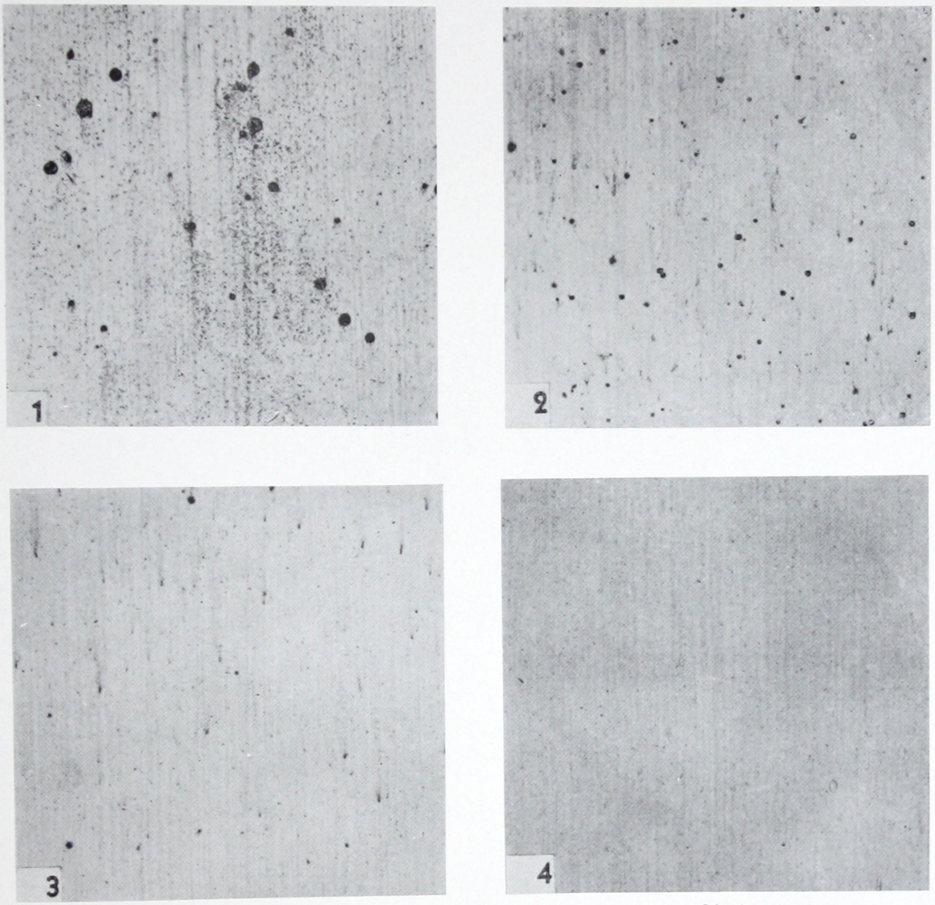


A—Zinc Sulfide *B—Zinc Sulfide-Barium pigment*
C—Titanium Dioxide *D—Titanium-Barium pigment*

The top half of each panel is without Zinc Oxide.
The bottom half of each panel contains 25% Zinc Oxide.
(Exposed in a mildew test cabinet.)

Effectiveness of Zinc Oxide for controlling mildew on interior mill gloss paints.

FIGURE 14



1—0% Zinc Oxide
3—13.0% Zinc Oxide

2—6.5% Zinc Oxide
4—19.5% Zinc Oxide

(Panels exposed 1½ years at Palmerton, Pa. Larger amounts of Zinc Oxide will be required to stop mildew in more humid localities.)

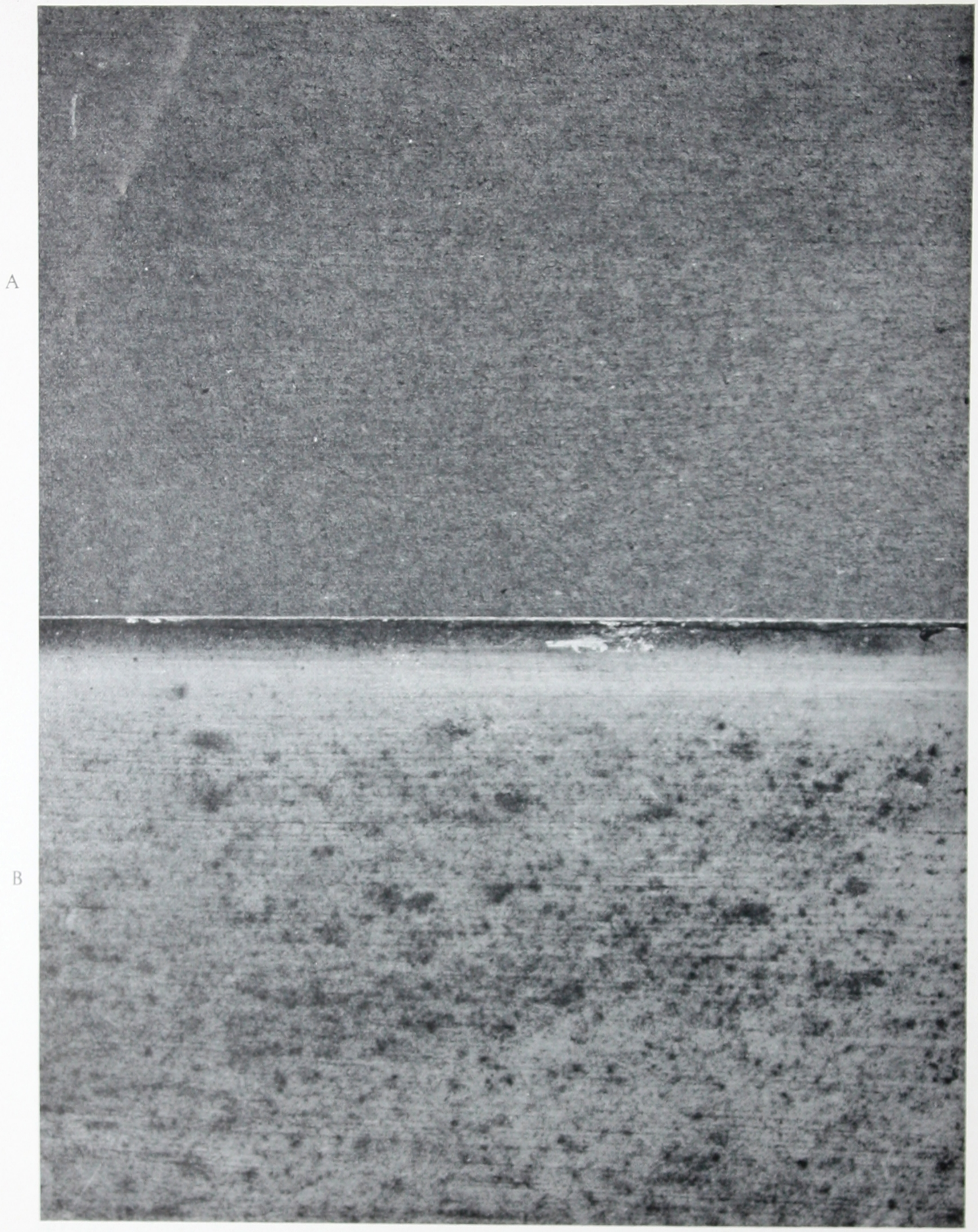
Effect of increasing Zinc Oxide content for improving mildew control on house paints.

FIGURE 15

the proper balance of zinc oxide is maintained, as shown by Figures 11 and 12. This might to some extent be due to the effect of zinc soaps on the nature of the chalk, but it has been observed that the less reactive zinc oxides (XX-505) can be just as effective.

Washability and Ease of Polishing

These are, in a general way, associated with the tightness and continuity of the surface and body of the film that result when zinc oxide is present. Again, the complete contact between pigment and binder promoted by the reactivity of zinc



A—100% Iron Oxide *(paint completely eroded away.)*
B— 80% Iron Oxide
20% Zinc Oxide
(1 coat—exposed seven years—45°)

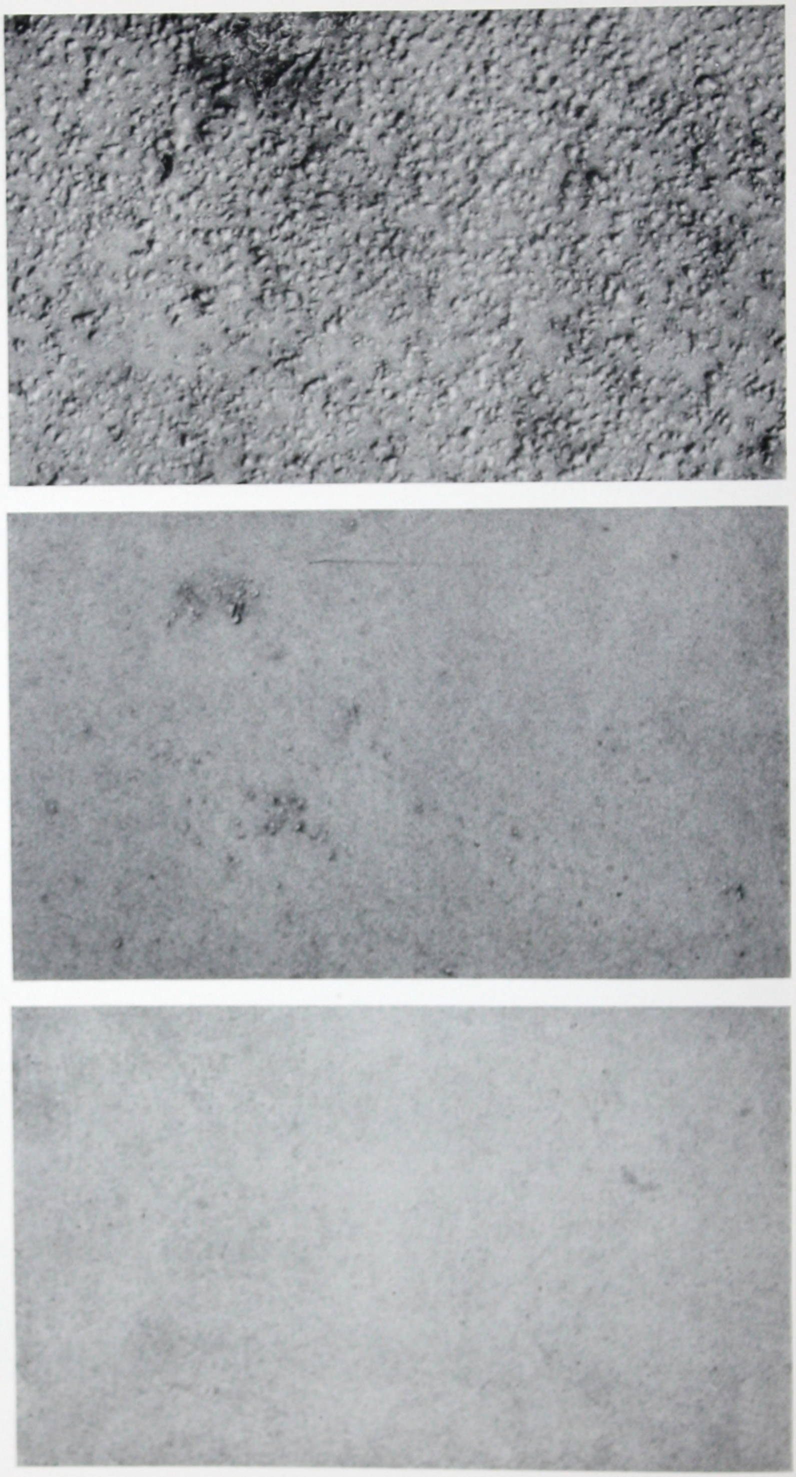
Improvement in weathering and rust inhibiting qualities by adding Zinc Oxide to Iron Oxide shop coats and primers.

FIGURE 16A

C—100% Lead Chromate (paint blistered and panel badly pitted.)
D— 80% Lead Chromate
20% Zinc Oxide
(1 coat—exposed seven years—45°)

Improvement in weathering and rust inhibiting qualities by adding Zinc Oxide to Lead Chromate shop coats and primers.

FIGURE 16B



A

65% Zinc Chromate
35% Magnesium Silicate

B

60% Zinc Chromate
20% Zinc Oxide
20% Magnesium Silicate

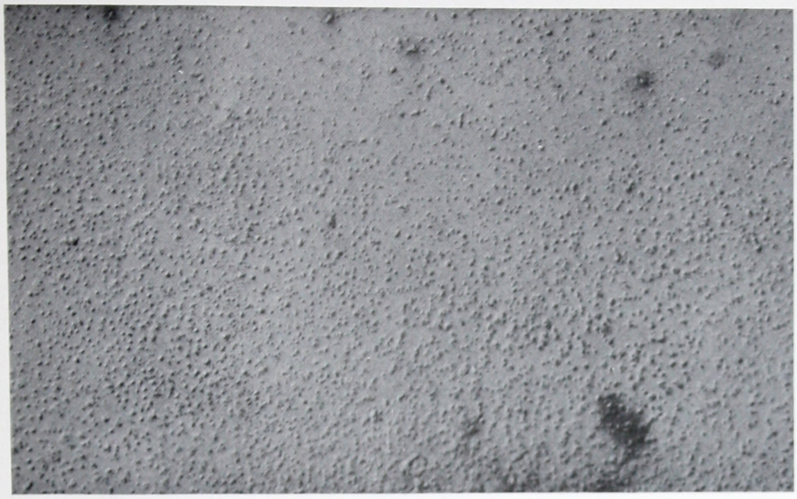
C

35% Zinc Chromate
35% Zinc Oxide
30% Magnesium Silicate

(1 coat—exposed four years—45°)

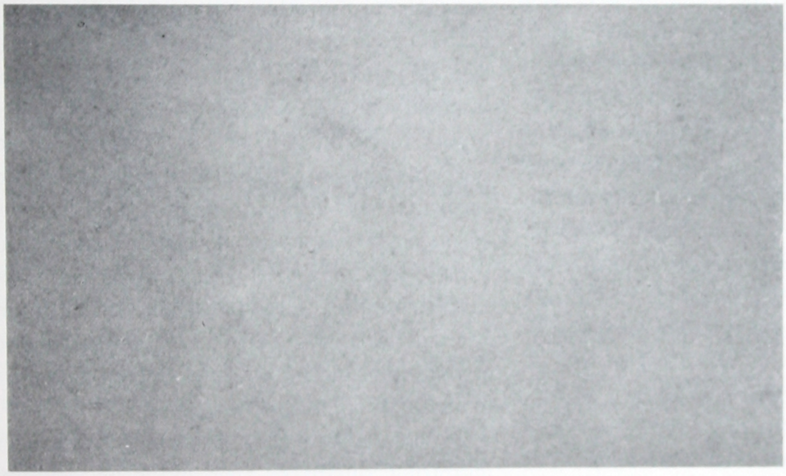
Improvement in weathering and rust inhibiting qualities by adding Zinc Oxide to Zinc Chromate—Magnesium Silicate shop coats and primers.

FIGURE 17A



D

35% Zinc Chromate
30% Magnesium Silicate
35% Iron Oxide



E

35% Zinc Chromate
30% Zinc Oxide
35% Iron Oxide

(1 coat—exposed four years—45°)

Improvement in weathering and rust inhibiting qualities by adding Zinc Oxide to Zinc Chromate—Iron Oxide shop coats and primers.

FIGURE 17B

oxide must be an important factor in the results, but polymerization of the binder would have similar effects. This is particularly true as applied to washability (ease of washing and resistance to its effects on appearance) of both interior and exterior paints. The same characteristics often facilitate the removal of dirt without the use of water on gloss and enamel surfaces.

Mildew Control

As previously mentioned, on page 12, the fungicidal action of zinc oxide is the result of its reactivity but is not associated with soap formation. Figures 14 and 15 illustrate how mildew control improves with the percentage of zinc oxide in the formula. Where bad mildew conditions have previously existed on a repaint job, it is particularly desirable, in addition to proper preliminary washing, to have plenty of zinc oxide in both coats. This has been repeatedly noticed and recently confirmed by investigators for the British Royal Aircraft Establishment, who report[12] that in controlling the growth of algae and barnacles on seaplanes, the presence of either zinc oxide or zinc dust in the undercoat is distinctly beneficial.

It follows, naturally, that zinc oxide is equally effective in interior paints of all types for use in damp locations, bakeries, breweries, etc., as illustrated by Figure 14, showing results on mill gloss paints with and without zinc oxide when exposed to bad mildewing conditions.

Blister Resistance

Although some relief can be obtained by changes in formulation, blistering on wood where the moisture comes in from the back can usually be cured only by removing the moisture condition, regardless of the formula that is used. However, on metal, where the moisture must come from the front through the paint film, it has been observed that zinc oxide counteracts the effects of other ingredients that tend to promote blistering in both air-dry and baked systems. Since polymerized vehicles are known to have good moisture resistance, it is reasonable to ascribe this to increased polymerization of the binder.

Neutralizing and Inhibiting (as Applied to Primers, Finish Coats, and Enamels for Metal)

Investigators[13] have recently confirmed the fact that zinc oxide is the most effective practical pigment for neutralizing acids of the types known to be formed in paint films during aging and weathering processes. Tests[8] have also shown that the inhibitive pigments used in primers are generally improved by adding a reasonable amount of zinc oxide (20% or more), and the need for it increases as the other pigments present in the formula go down in the scale of inhibitive qualities. Its neutralizing effect can also be important to highly inhibitive pigments of the chromate type if the paint is in service under acid atmospheric conditions because, under acid conditions, chromates may become oxidizing and stimulate corrosion.[14] The above points are amply illustrated by the results of industrial plant exposures shown in Figures 16A and 16B and Figures 17A and 17B. In the latter case, the elimination of the blistering type of failure by adding zinc oxide is particularly noticeable.

When pigments are classified with respect to inhibiting qualities, zinc oxide is definitely placed in the inhibiting class.[15] Aside from the influence of its neutralizing qualities, this might be expected since its pH value is slightly on the alkaline side, and an alkaline condition maintained next to the metal retards anodic attack.

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[8] Harley A. Nelson—Metal Priming Paints—Inhibiting Qualities and Influence of Reactions within the Paint Film—Industrial & Engineering Chemistry, Vol. 27, January 1935, p. 35.

[12] E. W. J. Mardles—Paints for Marine Service—Report on Investigation by British Royal Aircraft Establishment—The Chemical Trade Journal & Chemical Engineer, April 7, 1939, p. 333; April 14, 1939, p. 357.

[13] E. Rossmann, R. Haug, and A. Kiebitz—Testing Basic Properties of Pigments—Fette und Seifen, Vol. 45, 1938, pp. 503-509.

[14] S. C. Britton and U. R. Evans—The Scientific Study of Protective Painting—Transactions of the Electrochemical Society, Vol. 64, 1933, p. 51.

[15] R. M. Burns and A. E. Schuh—Protective Coatings for Metals—p. 306, A.C.S. Monograph No. 79. Reinhold Pub. Corp., N. Y., 1939.

WHERE AND HOW TO USE ZINC OXIDE IN PAINT

It is questionable whether any other pigment can serve as many useful purposes as zinc oxide. But, because of its positive properties, zinc oxide obviously must be used with reasonable care and discrimination. This is particularly true today when many types and modifications of zinc oxides are available, each with more or less distinctive qualities. It follows that these qualities must be considered for the manner in which they may influence the results in each product, and some specific discussion of the use of zinc oxide in individual types of paints is desirable.

Exterior Paints for Wood (House Paints, etc.)

Due to the variability of wood surfaces and other factors that add to the unpredictable nature of the service requirements, the development of a good exterior paint for wood becomes a masterpiece of compromise that requires more than ordinary knowledge about the properties of the ingredients. Zinc oxide is in excellent position from this standpoint, and knowledge about its properties and about the types that emphasize the qualities needed in the paint, has now put this versatile pigment in the position of being practically viewed as a necessity in the modern exterior paint field.

One generalization that can be made about the amount of zinc oxide* to use in an exterior oleoresinous type of paint is that the percentage should increase with the chalking type, high hiding pigment and silicious inert content of the pigment and the bodied oil content of the vehicle. While these have advantages, they also have weaknesses that can be overcome only by using zinc oxide. In most cases, 25% zinc oxide is the minimum that can be expected to have any appreciable effect on tint retention, controlled chalking, and growth of mildew, and promote proper self-cleansing of the film (See Figures 11, 12, 13 and 15, inclusive). 30% has been very popular but, the trend being toward the use of greater percentages of high hiding pigments and other ingredients that in themselves tend to form still softer films, the use of higher percentages of zinc oxide will become even more general.

The foregoing refers to white paints. For tints and many dark colors, the use of from 35 to 50% zinc oxide has long been common practice to aid color retention.

Because of the variability of wood surfaces, some have considered it necessary to use special primers under a finish coat (or coats) rather than old established, self-primed painting systems. These special primers are conceived as more plastic intermediaries that will follow the physical changes of the wood surface and thus serve as bonding agents, and on the basis of this reasoning zinc oxide is sometimes omitted. However, this may often be a serious mistake because the primer remains too plastic for the finish coat, which must be formulated to withstand weathering. A safer course is to include 10 to 15% zinc oxide in the primer formula to insure compatibility and avoid failures of the finish coat, which are likely to show up in the form of alligatoring, coarse checking or actual film separation (See Figure 8).

House paints often show special advantages that can be traced to the zinc oxide in the formula. One such familiar characteristic is the better uniformity of film structure that is promoted by zinc oxide, which is an advantage in undercoaters and special primers as well. It is due to the fact that zinc oxide is more completely wetted by the vehicle than the less reactive pigments and, consequently, tends to prevent the binder from soaking into the localized areas that happen to be more porous. This advantage shows up particularly where single-coat repaint jobs are done. In such cases the repaint coat containing zinc oxide will not only appear more uniform at the outset, but will also weather more uniformly without showing "flat" spots over the more porous areas.

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*In all cases, the percentages refer to the actual amount of zinc oxide in the pigment formula and do not take into account incidental ingredients, such as the basic lead sulfate in leaded zinc oxides.

Although the reactive property of zinc oxide serves many useful purposes in exterior paints, it can be over-emphasized, so the use of a fine particle size zinc oxide generally should be avoided. There has been considerable discussion of the part that particle shape plays in the durability obtained with zinc oxide in house paints. Extensive tests have been made with nodular and acicular zinc oxides and good durabilities are obtained with both types if properly made. Neither type can be considered a cure-all because zinc oxides will behave somewhat differently in different formulas, and because of the variable nature of service requirements. Also, the extremes of either type will usually show some markedly individual characteristics that may be considered either advantageous or disadvantageous, depending on circumstances. For example, while a highly acicular zinc oxide will delay surface checking where the formula has that tendency, acicular particles often promote a longitudinal slitting type of ultimate failure. On the other hand, a strictly nodular zinc oxide may show earlier surface checking, but the pattern is more likely to be uniformly distributed and is less likely to develop into ultimate failure of a localized slitting type.

In view of this situation, and because factors other than particle shape also enter into the results, the logical trend is in the direction of compromises between the two extremes. However, in considering shape differences as a factor in durability, the information obtained by merely looking at photomicrographs is not final or very reliable. Most important is careful control of manufacture, and since zinc oxides specially designed and tested for exterior service are now generally available, only these should be used in formulating the standard types of exterior paints.

If, for a specific reason, a large particle size zinc oxide is to be used, the lower surface area of the pigment per unit volume should be taken into account by increasing the pigment–fixed vehicle ratio (P.F.V.) in the paint. The true relationship of pigment to fixed vehicle should be based on the surface area of the pigment, and not alone on the pounds of pigment or on the pigment volume calculated from an arbitrary specific gravity figure. This is evident when we consider that the surface areas of zinc oxides that are largely used in exterior house paints range from approximately 2.5 square meters per gram (approximately 12,000 square feet per pound) for the smaller particle sizes to 0.6 square meter per gram (approximately 3,000 square feet per pound) for the larger sizes. Fortunately, for practical purposes in house paint formulation, the proper correction to compensate for any such reduction of pigment surface in the usual linseed oil vehicles is generally indicated by the increased pigmentation required to obtain equal painting consistency if no changes are made in the vehicle.[16]

Leaded zinc oxides, usually containing either 35% or 50% basic lead sulfate (actually mixtures of normal and basic lead sulfates) have become popular because they provide a combination of zinc oxide and lead in convenient form. Two types of leaded zinc oxides, co-fumed and blended, are in use. Both are generally satisfactory and the processes by which they are obtained may properly be disregarded. The co-fumed product, which is the older type, is a satisfactory product for durability although limited in some of its other properties. However, the present knowledge about zinc oxide makes it practical to mix zinc oxides specially designed for use in exterior paints with basic lead sulfate and obtain leaded zinc oxides of the blended type equal to, or better than, the co-fumed products in durability, but without their limitations in other properties.

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[16] A. C. Elm—Paint Durability as Affected by the Colloidal Properties of the Liquid Paint—Ind. & Eng. Chemistry, Vol. 26, p. 1245, December 1934.

The belief has been rather general that some combination product of zinc oxide and lead sulfate is formed when a leaded zinc oxide is co-fumed. According to X-ray evidence, there is no indication of compounds of lead or zinc being formed that are not obtained when zinc oxide and basic lead sulfate are produced separately. The evidence of this similarity of the mixtures is shown by the X-ray diffraction patterns in Figure 5, and is further substantiated by the similarity of the ultra-violet photomicrographs of two such leaded zinc oxides, as also shown in Figure 5.

Exterior Paints for Metal Surfaces

The versatility of zinc oxide in the metal priming paint field lies in the fact that it can function as a practical suspending agent for the heavy priming pigments while it also contributes weather resistance and, in addition to being in the inhibitive class, aids the other inhibitive pigments by counteracting undesirable acid conditions within the film.

There really are two classes of primers for steel, namely, the so-called shop coats, and those over which finish coats are applied at once. Shop coats must be designed to withstand the weather under a variety of yard storage and erection conditions for periods up to possibly two years, or even more. This fact, and the fact that some of the best inhibitive pigments are notoriously susceptible to weather, make the inclusion of zinc oxide in shop coat formulas a logical step. 15% to 20% zinc oxide (based on total pigment) is usually sufficient to build up the weather resistance to a practical degree. However, in the case of the chromate-type primer pigments, the weather resistance is relatively low and the avoidance of acid film conditions so important that the use of as much as 30% zinc oxide should be considered, as suggested by the results shown in Figures 16B, 17A and 17B. In these cases, the marked reduction in blistering type of failure when zinc oxide is added deserves special attention.

The marked effect of zinc oxide on a relatively non-inhibiting but weather-resistant paint is best illustrated by the improved results when about 20% zinc oxide is added to iron oxide, as shown in Figure 16A. When such combinations are further stepped up by substituting other inhibitive pigments for iron oxide, as in the case of zinc dust, in proportions to produce a combination such as 50-20-30 zinc dust-zinc oxide-iron oxide, the results are highly satisfactory from a practical point of view. This represents a principle for formulating weather-resistant, inhibitive paints which will, moreover, produce better results with any pigment in the inhibitive class.

In special primers of the zinc dust type for galvanized iron, zinc oxide (20%) is added primarily to serve as a suspending agent for the metallic pigment. The use of zinc oxide is preferred because it has no serious effect on the adhering qualities. Similarly, zinc oxide can be used to good effect in zinc chromate primers for finishes on magnesium and aluminum alloys.

Finish coats for metals for industrial parts and structures must be designed to meet a wide variety of conditions and often require special formulation. However, formulations of the type used for general exterior service give excellent service under average conditions, provided they are fortified with sufficient zinc oxide to take into account the more rapid chalking and erosion that usually occur on metal surfaces. This is particularly true over primers containing pigments like lead that have the effect of driers and promote oxidation of the binder that comes in contact with them.

It is generally better to avoid using the highly reactive, fine particle size zinc oxides in maintenance paints for metal. While neutralizing power is important, it should obviously be tempered to last over an extended period, and the use of larger amounts of the less reactive zinc oxides is a sounder basis on which to formulate.

Exterior Paints for Concrete, Stucco, Brick and Asbestos Shingles

The best practice in pigment formulation for normal cement-containing or masonry-type surfaces, in general falls in line with the best practice for exterior paints for wood. Chalking, erosion, and mildew are likely to be accentuated on such surfaces, so it is desirable to keep the zinc oxide content on the high side. This means that from 30 to 50% is desirable, depending on the color of the paint. The zinc oxides used should again be the moderately or less reactive types that are recommended for exterior paint service. Other special service requirements arising from alkaline surface conditions must be taken care of by adjustments in the vehicle to make the binder more alkali resistant.

Exterior Enamels

Aside from general uses, such as aiding the dispersion of pigments that are difficult to disperse, improving leveling and suspension, and promoting through drying (preventing wrinkling due to top driers), the more specific functions of zinc oxide in enamel type products for exterior service are to reduce color change, improve gloss retention, reduce chalking, and improve durability in general by eliminating blistering failures. If enough zinc oxide is used to markedly reduce chalking when the other pigments present are of the free chalking type, which varies from 20 to 50%, gloss retention and color changes (yellowing and loss of tint) will be taken care of, as well as mildew conditions encountered in some localities. Also, many resin type vehicles sometimes have effects on tinting materials that cause pronounced color changes even before chalking occurs. In such cases, the presence of zinc oxide often prevents the difficulty.

Another very important quality of exterior enamels containing zinc oxide that seems to apply to all types of vehicles is that their weathered surfaces are more easily washed free of dirt, and take a polish with less work than similar coatings without zinc oxide. This is important in automobile enamels. In fact, good results can often be obtained by merely wiping a zinc oxide-containing enamel with a dry cloth alone, whereas a zinc oxide-free enamel requires both polishing and waxing. In some vehicles, this advantage will show up with as little as 15% zinc oxide.

Where baking of the finish is involved, the particularly useful functions of zinc oxide are to obtain uniform hardening throughout the film and to retard color change (yellowing) during the baking operation. These purposes can sometimes be accomplished with as little as 10% zinc oxide but other considerations, as mentioned above, generally favor higher percentages.

Good exterior enamels can be made with a wide selection of zinc oxides and all types, from the colloidal to those in the coarse range, have been used successfully, but those in the intermediate particle size range are favored. However, a recent development is that zinc oxide of lower reactivity (XX-505) has shown indications of better cleansing, gloss and tint retention, which will undoubtedly make the advantages of zinc oxide available in many enamels containing more reactive vehicles.

Exterior nitrocellulose lacquer enamels represent a striking example of a case where chemical and optical properties of zinc oxide combine to produce desirable results. Nitrocellulose decomposes readily under ultra-violet light, and the decomposition products discolor the film and also catalyze the decomposition. Zinc oxide breaks up this cycle both by intercepting the ultra-violet radiations and neutralizing the acid decomposition products.

Nitrocellulose enamels as made today usually carry modifying resins. Where resins such as ester gum and dammar are used to modify the nitrocellulose, the presence of an appreciable amount (25% or more) of zinc oxide is still important because of their susceptibility to ultra-violet light. From the standpoint of durability the percentage can be reduced when alkyd resins are included, but for easier cleaning and polishing, reduced blistering failures, and the usual other advantages, zinc oxide should be present to the extent of 15 to 25%. In these exterior enamels highly reactive, fine particle size zinc oxides are likely to prove too drastic. Best results are obtained with the less reactive types.

Marine Paints

The combination of corrosive salt water, fungus growth, strong sunlight, and high humidity conditions long ago led to the practical discovery that the presence of zinc oxide is desirable throughout the entire range of marine paints—from anticorrosive primers and antifouling paints to finish paints and enamels—as exemplified by the instructions for painting vessels of the United States Navy.[17] Many interesting efforts have been made to take special advantage of the properties of zinc oxide in the marine painting field. One example is the practice followed by the United States Coast Guard, and others, of applying a zinc oxide-gum turpentine mixture (5 pounds to 1 gallon)[18] as a primer on all underwater areas that are touched up in the dry dock in order to neutralize the surface and prevent pitting under the repaint.

The exacting requirements of modern seaplane service, as recognized by the British Royal Aircraft Establishment, are again calling attention to the usefulness of the fungicidal properties of zinc oxide.[12] Besides being generally desirable as part of the pigment in both undercoats and finishes, to discourage the adhesion of algae and barnacles, zinc oxide used in water-resistant smears or pastes that can be rubbed on the more susceptible areas, such as the pontoons, has proved distinctly helpful.

For general service, wherever a higher hiding pigment that produces a soft, chalking type of film is to be used in marine paints, the percentage of zinc oxide should be increased 10 to 25% over the percentage that would normally be used in the same type of formula for service on land. Under tropical exposure conditions, 75 to 80% of zinc oxide with a high hiding pigment can often be used to advantage for resistance to chalking, abrasion (washing), and fungus growth. Zinc oxides of the American process type that are designated for general exterior service are the most satisfactory.

Traffic Zone Paints

Although various schemes have been proposed for inserting permanent traffic direction markers in streets and highways, the ease with which changes and rearrangements can be made maintains the popularity of traffic paint. The important demands on such paints are abrasion and weather resistance, balanced with good average adhesion to different types of road surfaces. Zinc oxide is depended on to add abrasion and weather resistance. From 20 to 40% is used, and the types designed for general exterior exposure (house paints, etc.) are preferred.

Interior Wall Paints — Flats, Semi-glosses, and Gloss Paints

In flat wall paints, zinc oxide serves to control consistency and improve resistance to washing, yellowing, and mildew. Undercoaters, in addition, emphasize the necessity for better sealing and leveling. In general, 5 to 15% zinc oxide, depending on the vehicle, will contribute these qualities in both types of paint. On the other hand, semi-gloss and gloss paints, such as mill whites, require properties that are still more dependent on zinc oxide additions—notably better flow, leveling, anti-yellowing, and increased gloss and gloss retention. The need for zinc oxide increases as the gloss factor increases, the amounts used in practice ranging from about 15 to 30% of the pigment. The best combination of properties is generally obtained with the moderately reactive zinc oxides.

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[12] E. W. J. Mardles—Paints for Marine Service—Report on Investigation by British Royal Aircraft Establishment—The Chemical Trade Journal & Chemical Engineer, April 7, 1939, p. 333; April 14, 1939, p. 357.

[17] Instructions for Painting and Cementing Vessels of the United States Navy, Edition of April 1939.

[18] Instructions for Painting United States Coast Guard Vessels, Boats, and Stations, 1935, p. 35.

Interior Enamels

Where oil varnish architectural finishes are involved, zinc oxide can serve all of the purposes that have been mentioned in connection with wall paints. With interior enamels, however, there is such need for emphasis on properties obtained with zinc oxide that higher percentages are desirable all along the line. The best examples are the long oil enamels made with the highest grade French process type zinc oxides with their excellent packaging qualities, good leveling, holding-out qualities, high gloss and gloss retention, good color, resistance to yellowing or change in tint, and washability. All of these combine to produce products with such enviable service records that they still set the standards for more recent developments in faster drying and higher hiding products. In fact, the present problem is to retain as many as possible of the good qualities of these enamels and still meet modern demands for speed. With zinc sulfide and titanium dioxide available, it has been possible to step up hiding power by adding 10 to 25% of these high hiding pigments to the zinc oxide without seriously disturbing other properties. The endeavor to use synthetic resins for speeding up drying without disturbing other properties has been a more complicated problem.

Gloss retention of high grade, air-dry, synthetic finishes is a live question. As the reactivities of the vehicles have permitted, small amounts (2 to 10%) of the more reactive zinc oxides have been used with distinct improvement in the results in many cases. However, very favorable results are now being obtained with recently developed, less reactive, synthetic resin vehicles, in which zinc oxide can be used as 25 to 75%, or even 100%, of the pigment. Where the vehicle has poor wetting qualities, the addition of zinc oxide will aid in the dispersion of pigments that are not readily dispersed. In such cases, 40% or more of a reactive zinc oxide will often produce the maximum gloss results with the minimum amount of milling.

The ability of zinc oxide to eliminate or minimize yellowing of synthetic resin enamel films when exposed to diffused light, as in a room, is even more marked than when such films are exposed to direct sunlight. To obtain maximum results 15 to 20% zinc oxide should be used. For this purpose, the normally reactive zinc oxides of the French process type are usually most efficient but, where the vehicle is too reactive, the possibilities of less reactive zinc oxide (XX-505 type) should not be overlooked. The amount necessary for obtaining results with any given zinc oxide depends on the vehicle and the resin it contains. Here, again, the presence of zinc oxide contributes to color stability and good general film properties if 10 to 20% is present.

Interior Enamels — Baking Types

In enamel finishes designed for baking, the two major functions of zinc oxide are to help obtain uniform hardening throughout the film, and to retard yellowing during the baking operation and later in service. In addition, zinc oxide generally contributes improved pigment suspension, leveling and gloss. The amounts needed depend on the nature of the vehicles, especially the resin that is used. In general, vehicles with higher oil content require more zinc oxide, but are quite responsive to its presence. 10 to 25% zinc oxide is the useful range for average products, but for vehicles with the more reactive resins, even 2 to 3% may produce surprising improvements. Because of the importance of color, the better French process type zinc oxides are mostly used, and in some formulations successful use has been made of the very reactive (Kadox) grade.

In baking primers, also, zinc oxide is an essential where sealing and blister resistance under exposure to moisture are necessary. For example, it is well known that the ultimate results in blister resistance of refrigerator finishes exposed to sweating or condensation are obtained with a zinc oxide-synthetic resin type primer in which the percentage of zinc oxide is maintained as high as circumstances permit. The moderately reactive zinc oxides are generally used in such products.

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PRINTED IN U.S.A.
BY
MARBRIDGE PRINTING COMPANY, INC.